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MULTILEVEL INVERTER SOLUTION FOR PRESENT INVERTER IN LOCAL TRAINS IN MUMBAI

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ABSTRACT

In this paper presents literature survey for the implementation multilevel inverter in Mumbai Local Trains. Also present latest inverter system implemented in the local trains. This will also give the information about the Total Harmonic Distortion in the traction system. Initially Total Harmonic Distortion and losses due to that will be considered for the present system inverter and various topologies are studied with their advantages and disadvantages.

KEYWORDS: Multilevel Inverter, Total Harmonic Distortion, Electric Traction

INTRODUCTION

Due to the improvement of fast-switching Power-electronic inverters are becoming popular for various industrial drives applications. In recent years also high-power and medium-voltage drive applications have been installed. To overcome the limited semiconductor voltage and current ratings, some kind of series and/or parallel connection will be necessary. Due to their ability to synthesize waveforms with a better harmonic spectrum and attain higher voltages, multi-level inverters are receiving increasing attention in the past few years The multilevel inverter was introduced as a solution to increase the converter operating voltage above the voltage limits of classical semiconductors. The multilevel voltage source inverter is recently applied in many industrial applications such as ac power supplies, static VAR compensators, drive systems, etc. One of the significant advantages of multilevel configuration is the harmonic reduction in the output waveform without increasing switching frequency or decreasing the inverter power output. The output voltage waveform of a multilevel inverter is composed of the number of levels of voltages, typically obtained from capacitor voltage sources. The so-called multilevel starts from three levels. As the number of levels reach infinity, the output THD (Total Harmonic Distortion) approaches zero. The number of the achievable voltage levels, however, is limited by voltage unbalance problems, voltage clamping requirement, circuit layout, and packaging constraints. Multilevel inverters synthesizing a large number of levels have a lot of merits such as improved output waveform, a smaller filter size, a lower EMI (Electro Magnetic Interference), and other advantages. The principle advantage of using multilevel inverters is the low harmonic distortion obtained due to the multiple voltage levels at the output and reduced stresses on the switching devices used. To avoid these problems several solutions have been developed. One of them is introducing additional output filter. This method is questionable for high current drives because of voltage drops on filter passive components and additional losses. The concept of multilevel power conversion came to has article since from 1975 and term multilevel began with the three-level converter first time by Nabae. Subsequently, several multilevel converter topologies have been developed and proposed. But however, basic concept of multilevel converter achieving higher power rating by using a series of semiconductor switches with several low voltage dc sources to perform the power conversion by synthesizing a staircase voltage waveform. Capacitors, batteries, and renewable energy systems used as the multiple dc voltage sources.

The commutation of the power switches aggregate these multiple dc sources in order to achieve high voltage at the output; however, voltage rating of the power semiconductor switches depends on rating of dc bus to which they are connected. The attractive benefits of multilevel converters when compared with conventional 2-level converter are briefly summarized as follows:

- **Quality of Output Voltage:** Multilevel converters generate the output voltages with very low distortion, additionally reduce the dv/dt stresses; therefore electromagnetic compatibility (EMC) problems significantly minimized.
- **Quality of Input Current:** Multilevel converters draw input current with very low distortion.
- **Quality of Switching Frequency:** Multilevel converters can modulate with fundamental and also higher switching frequency PWM. By lower switching frequency provides lower switching loss and higher efficiency.

Quality of Reducing Common Mode Voltage

Multilevel converters produce smaller common mode (CM) voltages; therefore, the stress in the bearings of a motor can be lowered. Further common-mode components could eliminate by using advanced PWM strategies. Even though with all above merits, multilevel converters do possess some drawbacks in particular with greater number of power switches. Lower voltage rated switches can utilized in a multilevel converter, but each switch requires related gate driver circuit. Hence, the overall system becomes expensive with complex control. In next section, most addressed available multilevel converter structures are discussed relating to survey of optimal configuration solution.

LITERATURES SURVEY REGARDING TOTAL HARMONIC DISTORTION, IMPLEMENTATION OF MULTILEVEL INVERTERS IN TRACTION

Reduction of Harmonics

N. Gunavardhin, M. Chandrasekaran, A. D. Thirumoorthy [1] have done the study on two railway traction sub-stations. One is Salem 110KV Railway traction where 2400 KVAR rated capacitor bank alone is installed and another is Bommidi 110 KV Railway traction where IGBT based Dynamic Reactive Power Compensation (DRPC) with 1800 KVAR is connected along with fixed 2400KVAR capacitor bank. The harmonics due to load currents are measured and compared in both the sub-stations based on IEEE Standards 519-1992. Shu-Guang Sun, Jing-Qin Wang, Shun-Quan Shi[2] have done the work on detection of harmonics and reactive currents of active power filter (APF) The former is the detection method based on the character of triangle function and some improvements are done; The latter is the detection method based on the theory of adaptive linear neural network. Yu Han, Cui Zhengpai, Li Sheng, Liu Qihui, Long Yunbo, Zhang Jianhua [3] presents an approach to the detection of harmonics and reactive currents in single-phase circuit according to the orthogonal characteristic of sine function. The method is simple and practical, which cannot only detect the current component in the distorted current but can also obtain the sum of the active and reactive current. H. J. Chuang, C. S. Chen, C. H. Lin, and H. M.Shiau [4] investigate the stochastic harmonic distortion of an mass rapid transit (MRT) system by considering the dynamic load behavior of train sets. The mathematical model of 12-pulse uncontrolled rectifiers without interphase transformers has been used in the harmonic load flow analysis to solve the power demand and harmonic current injection for each time snapshot. I. Zamora1, P. Eguia2, A. J. Mazón, E. Torres, K. J. Sagastabeitia [5] the simulation of an active filter for the reduction of the current harmonic distortion of an underground traction system is presented. Karel HLAVA, Radovan DOLEČEK [6] deals with the wave distortion analysis of the contact system line voltage at the operation of electric motive power with diode traction converters. The ascertained harmonic values are important for the prepared european standards and guidelines about interoperability not only from the point of view of the

energy measurements on board trains working conditions, but also from the point of view to insure the regenerative breaking safety of new AC motive power. Adrian David Cheok and Shoichi Kawamoto, Takeo Matsumoto, and Hideo Obi [7]work on advanced control techniques lead to a unity power factor seen by the ac supply as well as minimizing the line harmonics, power loss, motor torque ripple, and audible noise.

By using advanced ac inverter drive systems the recently developed high speed train offers high level performance, efficiency, and passenger comfort. The described system is implemented in the latest “Bullet” or Shinkansen train sets operating in eastem Japan between Tokyo and Nagano. Vasanthi V, and Ashok Sinvestigate [8] the harmonics of Electric Traction system in Indian railways by taking measurements at 110/25kV traction substations. This also calculates the total harmonic distortion of current and voltage harmonics in the feeder of the traction substation. Urmila Bandaru, Subba D Rayudu [21]presents a comparative study of orientation of higher ordered harmonics with increase in switching frequency around the frequency modulation index of nine level diode clamped inverter for different Switching frequency Multicarrier Pulse width Modulation. Shouji Onda*, Katsumi Maekawa[22]presents a paper on hysteresis based current control PWM named “Hi-PWM”, which has several advantages such as quick response of current, less fluctuation of switching frequency and less harmonic components.

Voltage, Current and Noise Harmonics

K. Kim, et al. [85], presented in this literature is proposed a new hybrid RPWM technique in order to disperse the acoustic switching noise spectra of an induction motor drive. The proposed RPWM pulses are produced through the logical comparison in this literature. It has been observed that total harmonic distortion in Indian Railway is 16.64%.

Multilevel Inverters

Rokan Ali, AhmedS. Mekhilef, Hew Wooi Ping **[11]** explain new topology for symmetrical and asymmetrical multilevel inverter is introduced. Both types have many steps with fewer power electronic switches, which results in reduction of installation area and cost and have simplicity of control system. José Rodríguez, Jih-Sheng Lai and Fang Zheng Peng [12] presents the most important topologies like diode-clamped inverter (neutral-point clamped), capacitor-clamped (flying capacitor), and cascaded multicell with separate dc sources. Emerging topologies like asymmetric hybrid cells and soft-switched multilevel inverters are also discussed. This paper also presents the most relevant control and modulation methods developed for this family of converters: multilevel sinusoidal pulse width modulation, multilevel selective harmonic elimination, and space-vector modulation. Amit Kumar Gupta, and Ashwin M. Khambadkone [13], proposes a simple space vector pulse width modulation algorithm for a multilevel inverter for operation in the over modulation range. The proposed scheme easily determines the location of the reference vector and calculates on-times. Longhua Zhou, Qing Fu, Xiangfeng Li and Changshu Liu [14] proposes a novel Multilevel Power Quality Compensator (MPQC).

This novel MPQC is composed of two single-phase cascaded inverters by sharing the DC capacitors each cascaded Inverter is made of two cascaded H-bridge inverters and the ratio of the DC voltage is 3:1, then, connects to traction power system via grid-transformer. R. W. Menzies, **,** P. Steimer**,** and J. K. Steinke[15]**,** investigates the use of a five-level GTO voltage-sourced inverter for large induction motor drives, The advantages of such a drive are that single GTO thyristors may be used at each level, thereby avoiding the need for series connection of the thyristors. The thyristors are well protected from over voltages by the clamping action of the dc supply capacitors. Hyo L**.** Liu, Gyu H**.** Cho, and Sun **S.** Park [16] done the comparative studies between harmonic elimination and optimal PWM strategies are given for high power three level inverter feeding induction motor. An effective PWM map construction method based. Jie Zhang [17]

presents a high performance control of a cage induction motor drive fed by a 100 Hp three-level IGBT inverter operating at a low switching frequency. J.Shen and N. Butterworth [18] analyses the merits and demerits of three-level PWM converters through the comparison with two-level PWM converters. A general method for analyzing the switching modes of PWM converters is described and an analysis of the three-level PWM converter is presented as an example. Wensheng Song, Xiaoyun Feng, and Keyue Smedley[19] proposes a control and modulation scheme for the single-phase three-level NPC converter. Firstly, an active and reactive current decoupled control scheme in d-q synchronous frame is presented for single-phase three-level NPC converter to reduce the influence between the traction power supply fluctuating voltage and the traction drive system. Secondly, a new space vector PWM (SVPWM) scheme is provided to restrict the voltage step of the input port voltage within half of DC-link voltage. Shutian Zhang, Lin Wu, Congwei Liu, Longcheng Tan, Qiongxuan Gel [20] presents a three-level neutral point clamped (NPC) back-to-back converter with IGCT for high power ac drive. The power circuit topology of the three-level NPC back-to-back converter and the hardware control system based VMEBUS and TMS320F28335 DSP are introduced.

Urmila BANDARU, Subba D RAYUDU [21] presents a comparative study of orientation of higher ordered harmonics with increase in switching frequency around the frequency modulation index of nine level diode clamped inverter for different Switching frequency Multicarrier Pulse width Modulation. Juan W. Dixon, Micah E. Ortúzar Luis A. Morán explain [22] the converter, with their 81 levels of voltage, can generate an excellent voltage waveform. The advantages and drawbacks of this kind of converter have been discussed. Juan W. Dixon, Micah Ortúzar and Felipe Ríos [23] investigated T the main advantage of this kind of topology is that it can generate almost perfect current or voltage waveforms, because it is modulated by amplitude instead of pulse-width. That means that the pulsating torque generated by harmonics can be eliminated, and power losses into the machine due to harmonic currents can also be eliminated. Juan Dixon, Javier Pereda, Carlos Castill and Sebastián Bosch [24] focused on a 27-level asymmetric inverter, but the strategy, using only one power supply, can be applied to converters with any number of levels.

Summary of the Paper

The following tables give summary of the paper as:

Table 1: Reduction of Harmonics Point of View

Parameter	Total No. of Literatures Review Out of 45 Literatures	% of Literature Reviews Out of 45 Literatures
Voltage harmonics	09	20
Current harmonics	08	17.77
Voltage and current harmonics	12	26.67
Harmonic distortion factor	10	22.22
Multilevel inverters	14	31.11

Reduction of Harmonics by Various Techniques

From above tables 1, it is concluded that the 20% of total literatures are reviews based on Voltage Harmonics, 17.77% of total literatures are reviews based on Current Harmonics, 26.67% of total literatures are reviews on based Voltage & Current Harmonics, 22.22% of total literatures are reviews on based Harmonics Distortion Factor (HDF), 31.11% of total literatures are reviews on based multilevel inverter. Finally it is concluded that the maximum research work carryout on multilevel inverters.

No. of Switches, No. of Levels, Space Vector Method and Other Methods in Multilevel Inverter

Table 2: Different Methods in Multilevel Inverters

Parameter	Total No. of Literatures Review Out of 34 Literatures	% of Literature Reviews Out of 34 Literatures
No of level	12	35.29
No. of switches	8	23.53
Other methods	10	29.41

From above table no 2, it is concluded that the 35.29% of total literatures reviews based on no. of level used in multilevel inverters (2-level to 81- level).based on no. of switches is 23.53%. Other methods like space vector method, capacitor charging method, wawelet transform method is 29.41%.

CONCLUSIONS

This paper has been addressed a survey of several technical literature concerned with total harmonic distortion and multilevel inverter. There are various methods for reducing the THD. But among all implementation of multilevel inverter method will be more effective. A literature survey also show that the achieve significant improvements in operating parameters of the multilevel such as reduction harmonics such as voltage, current harmonics, power factor, switching frequency, and others parameters. Authors strongly believe that this survey article will be very much useful to the researchers for finding out the relevant references as well as the previous work done in the field of reduction of harmonic and implementation of multilevel inverter for reduction of harmonic loss. So that further research work can be carried out. Even through, excellent advancements have been made in classical method i.e. harmonics distortion factor they suffer with the following disadvantages: In most cases, mathematical formulations have to be simplified to get the solutions because of the extremely limited capability to solve real-world large-scale multilevel inverter.

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